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Emissions Trading Hybrids: The Case of the EU ETS

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Abstract: We argue that the European Union Emissions Trading System (EU ETS) has evolved into a hybrid of two design variants, allowance trading (cap-and-trade) and credit trading (performance standard rate trading), with an added feature of industry support to minimize carbon leakage. In particular the current rules tying free allowances to production capacity expansion, plant closure and capacity use have transformed the efficient cap-and-trade program that stood at the origins of the EU ETS into a system that even surpasses credit trading in paying hidden product subsidies to firms. This combination of rules encourages an inefficiently high level of investment in production capacity and an inefficiently high output in industries exposed to international competition. The result is a sub-optimal EU Emissions Trading 'Hybrid' (which we therefore label as 'EU ETH').

Keywords: European Union Emissions Trading System, economic efficiency, cap-and-trade, performance standard rate trading, carbon leakage
JEL codes: D21, D62, K32, Q48, Q54

1 Introduction

The idea of creating pollution markets received considerable attention by some of the founding fathers of law and economics, such as Calabresi and Melamed (1972) building upon Coase (1960). The concept has moved from theory to practice and is now firmly embedded in environmental law. The European Union (EU), for instance, has been building up experience with carbon dioxide (CO_2) emissions trading since 2005 (e. g. Faure and Peeters, 2008). The original EU Emissions Trading Directive determines the rules applying in the first period 2005–2007 and the second period 2008–2012 (Directive 2003/87/EC). The

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European Parliament and the Council of the European Union have since adopted an amending Emissions Trading Directive introducing some new rules to apply in the current and third period 2013–2020 (Directive 2009/29/EC). Early 2018 the European Council approved another reform of the EU Emissions Trading System (EU ETS) for the next and fourth period 2021–2030 (Directive (EU) 2018/410). In this paper we aim to examine which rules have changed between the first and the third period and how efficiently the reduction of CO_2 emissions is currently being achieved under the EU ETS. Our economic analysis thus focuses on legal amendments made to the EU ETS so far (2005–2020), leaving an analysis of the next period's rules (2021–2030) for future research.

We start with a survey of the economic-analytical literature on emissions trading and use that knowledge to assess the efficiency of the original EU Emissions Trading Directive of 2003 and its deterioration due to the changes after 2013. We will explain why the additional rules applying to capacity expansion and plant closure lead to sub-optimal outcomes. A next set of new rules added an extra criterion for the allocation of free allowances by tying their number to the level of operations relative to capacity. Although this was possibly meant as a reparation, we will argue that this has in fact done further damage to the efficiency of the scheme. The various rather complex criteria for the allocation of free allowances did already receive attention by a number of scholars, such as Ahman and Holmgren (2006), Ellerman (2008), Christin et al. (2011), Meunier et al. (2014) and Branger et al. (2015). However, the niche of our paper is that we: (a) perform the analysis based on the conceptual distinction between allowance trading (cap-and-trade) and credit trading (performance standard rate trading); (b) use the current laws and regulations to model firm behaviour under the amended EU ETS; and (c) clarify - in two tables - how the successive revisions of rules in the past have affected corporate decisions and hence the efficiency of EU ETS.

In Section 2 the two basic systems are introduced in which emissions are traded with and without a fixed cap: allowance trading (cap-and-trade) and credit trading (performance standard rate trading), respectively. In a survey of the literature, provided in Section 3, the two blueprints are compared, in particular regarding their efficiency. In Section 4 we discuss the rules of the EU ETS that applied from 2008 to 2012 and then consider the new rules that apply from 2013 to 2020 (and beyond). In Section 5 it is shown that in the previous period 2008–2012 there is already some merging of the two basic concepts of emissions trading and that this merging has become more pronounced under the rules that apply from 2013 onwards. This leads us to argue that the EU ETS is increasingly becoming a hybrid system. Here we thus make a point that differs from Endres and Ohl (2005), who mention that the separation between a trading sector (covered by the EU ETS) and a non-trading sector (where the EU ETS does not apply) has created a hybrid system. Our contribution instead focuses on the features of the EU ETS itself as a hybrid offspring of two distinct emissions trading schemes which undermines its efficiency. The impact of the EU ETS on sectors exposed to international competition and on carbon leakage is the subject of Section 6. Conclusions are drawn in Section 7.

2 Two emissions trading concepts

In order to understand the economic consequences of the current legal design of the EU ETS, it is necessary to comprehend the conceptual difference between two basic variants of emissions trading (Nentjes and Woerdman, 2012). In the one system, trade is carried out subject to an emissions cap, which is referred to as 'cap-and-trade' (CAT) or 'allowance trading'. The other system is based on tradable emission reduction credits, also referred to as 'credit trading' (CT), 'performance standard rate trading' (PSRT), 'output-based allocation', 'tradable reduction certificates' or 'dynamic allocation'.

Law and economics literature traces the original concept of emissions trading back to Demsetz (1967), who argues that externalities should be internalized by allocating property rights, and ultimately to the exposition of Coase (1960) that bargaining will lead to a cost-efficient outcome regardless of the initial allocation of property rights (assuming transaction costs are negligible). In the environmental and resource economics literature, Crocker (1966) and Dales (1968) are mentioned as the first scholars to propose emissions trading in the specific form of cap-and-trade, with Montgomery (1972) as the one who provided the formal proof of its cost efficiency. The essence of cap-and-trade is the absolute cap on the total number of allowances, which is made available periodically either by handing them out for free or by way of auction. About twenty years after the birth of the concept of cap-and-trade, the United States (US) Congress turned it into actual policy in 1989 by making a cap-and-trade program for sulphur dioxide (SO_2) emissions the cornerstone of its strategy to control acid rain. The latter scheme started in 1995 and it succeeded to realize the planned cap on total emissions in 2007, three years before its statutory deadline of 2010. Despite its success, the US SO_2 trading program 'collapsed' in 2011 after a series of regulatory changes and judicial actions (Evans and Woodward, 2013).

Performance standard rate trading (PSRT), also referred to as credit trading (CT), did not start its life as a conceptual construct. In the process of implementing the Clean Air Act, the instrument evolved in the US in the 1970s and 1980s in subsequent steps, brought together under the label 'EPA emissions trading program'. This particular policy emerged to bring flexibility into the strict command-and-control regulation of emissions in areas with air quality worse than the national ambient standard. PSRT sets an emissions standard (or: intensity standard), which is usual in direct regulation, but supplements it with the option to compensate emissions higher than the standard at one source by emissions lower than the standard at another internal or external source. Therefore, PSRT is trade in reductions in emissions control that go beyond the reductions required by the performance standard. Tietenberg (1980, 1985:chpt. 1) provided a description and economic analysis of the trade in emission reduction credits (ERCs) under the EPA scheme, which is an early form of PSRT (Nentjes and Woerdman, 2012: 5).

It took more than two decades before the insight began to dawn that cap-and-trade and setting a performance standard with the option to trade emissions above and below the standard are instruments that differ not only in cost efficiency but also in their impact on the volume of output. The first step was set by Helfand (1991). In his basic model a ceiling on a firm's total emissions leads to the highest efficiency and to a lower level of output than setting a standard mandating emissions per unit. However, it took another decade before economists started to apply a similar analysis to a scheme of emissions standards where emission reduction credits are traded between sources and compared the outcome with cap-and-trade (e. g. Fischer, 2001; Dewees, 2001; Gielen et al., 2002; Woerdman, 2002:chpt. 5; Boom and Nentjes, 2003; Boom and Dijkstra, 2009).

The different histories of CAT and CT underline that the two are distinct instruments of environmental policy. The cap-and-trade system imposes a cap on the annual emissions of a group of companies for a period of years. The emission rights are allocated to established companies for the entire period, either for free or through an annual sale at auction (a combination is also possible). Newcomers and companies seeking to expand must purchase rights from established companies (or from a government reserve), while a firm closing down a plant can sell its emission rights. The system of tradable reduction credits, however, is based on a mandatory emissions standard (mandated emissions per unit of energy consumption or per unit of added value) adopted for a group of companies. Emission reduction credits can be earned by emitting less than is prescribed by the emissions standard. The credits can then be sold to companies who can use them to compensate their emissions in excess of the emissions standard applying to them.

3 Efficiency in emissions trading design

We will first discuss cost efficiency and then economic efficiency of emissions trading design. Cost efficiency means that abatement costs are minimized when companies aim for an emissions target at a given level of output. Economic efficiency means that welfare is maximized under an emissions target which can be achieved by reducing emissions or by reducing output. Below we will argue that economic efficiency is crucial for understanding the difference between cap-and-trade (CAT) and credit trading (CT).

3.1 Cost efficiency

Baumol and Oates (1971) demonstrated that prices can be put to more uses than internalizing environmental externalities, as proposed by Pigou (1920), namely to bring cost efficiency in pollution control. Cost efficiency or cost effectiveness is achieved when total emissions of the industry are cut back to the emissions target at the lowest possible abatement cost (e. g. Tietenberg, 2000:chpt. 3). In a CT scheme, companies with high compliance costs will buy emission reductions from companies able to comply with the emissions standard at a lower cost. The individual firm minimizes total compliance cost by abating up to the level where marginal abatement cost equals the market price of credits. The same is true under CAT, where the firm is free either to control emissions or to leave emissions unabated and buy allowances. Similar to CT, the individual firm minimizes total compliance cost by equalizing marginal abatement cost and market allowance price. The marginal control costs of all sources are equalized and consequently total control costs are minimal. Hence both CT and CAT establish a cost-efficient allocation of pollution abatement: it is the price set on not abating pollution and consequently rewarding control of emissions that gives firms the incentive to control emissions cost-efficiently.

3.2 Economic efficiency

We define economic efficiency as the maximization of the sum of consumer surplus plus producer surplus created by the production of an industry (e. g. Viscusi et al., 1992:chpt. 4). In environmental policy, this is equivalent to the minimization of the loss of surplus caused by reducing total emissions of an industry to the target level. Below we will show that CAT and CT differ in economic efficiency.

3.2.1 Decisions at firm level

A firm may achieve emission reductions by more intensive emission reductions at a given level of output or by lowering production itself. The firm will prefer to decrease output when this is less costly than using abatement technology. The problem with PSRT is that reducing total output does not save on abatement costs because it mandates emissions per unit of output. At a lower level of production, the emissions standard is still the same and as costly as before. CT only rewards the individual source for cutting back emissions below mandated emissions per unit of output. The sale of credits granted for these emission reductions enables the buyer to emit more than the standard requires. This transaction does not change the average emissions per unit of output of the industry, which remain equal to the standard set by the regulator.

CAT with free allowances works out differently because of the emissions cap (e. g. Nentjes and Woerdman, 2012). A firm that reduces emissions by cutting back production remains entitled to emissions equal to its cap. With output at a lower level it can choose an abatement technology that has lower costs because it leaves more emissions per unit of output unabated. Combining a relatively low level of output and high emissions per unit of output can be profitable for firms with high marginal abatement cost. They will select this option if less intensive abatement delivers a cost saving that exceeds the loss in net revenue arising from selling less output. In such a case, the industry under CAT thus operates at a lower level of output and higher emissions per unit of output than the industry would under PSRT.

The cap on firm emissions has the consequence that the allowances allocated for free to the firm are a cost of production. Free allowances used to offset emissions from production have an opportunity cost because the allowances have to be handed over to the authority and cannot be used a second time. The opportunity cost of allowances used up for a unit of output is equal to the cost of abating the emissions of the marginal unit of output, and simultaneously equal to the market price per allowance multiplied with the number of allowances needed per unit of output (e. g. Grafton and Devlin, 1996; Woerdman et al., 2008, 2009). The opportunity cost of free allowances is a component of the marginal cost of the product, as much as the expenditure for purchasing allowances at auction would be.

Free allowances under CAT thus differ fundamentally from the free mandated emissions under CT. Increase of output in a CT scheme entitles the firm to extra mandated emissions, which means that they cannot possibly be a cost of that output. However, the allowance price in a CAT scheme with auctioned allowances is not different from the market price in a scheme with free allowances (under perfect competition): the cost of allowances raises the market price of output in an identical manner. That said, we do note that auctioning allowances generates public revenues, which can be used to create a 'double dividend' by compensating for lowering taxes that distort incentives to work, save and invest (e. g. Goulder, 1995; Goulder et al., 1999).

Consequently, a firm under CT only pays for abatement and not for mandated residual emissions. The component lacking in the marginal cost of output is calculated by multiplying the mandated emissions of the additional product with either the marginal cost of abating emissions or with the price of an emission reduction certificate (Boom and Dijkstra, 2009). The non-included abatement cost of marginal output under a performance standard has been interpreted as an implicit output subsidy (Helfand, 1991), which also holds for PSRT (e. g. Fischer, 2001; Dewees, 2001; Boom, 2006:chpt. 4; Boom and Dijkstra, 2009; Holland, 2012). Bernard et al. (2007) classify the implicit subsidy as output-based rebating, which is a subsidy on output meant to offset the higher production costs caused by environmental regulation.

3.2.2 Market equilibrium and industry output

Because the mandated emissions in a CT scheme are not a cost for the firm, the marginal cost of output function and thus also the supply curve of the industry is situated below the same function and curve under CAT. In long-run market equilibrium, the price of output is therefore lower in CT than in CAT and the output of the industry is larger in CT than in CAT.

If emissions per unit of output are equal under both schemes, the higher level of output in CT would result in higher total emissions of the industry than in CAT, which is also what happened in lab experiments by Buckley et al. (2007). Therefore, assuming that the public authority wants to achieve a certain target level for the industry's total emissions, the performance standard under CT (in terms of emissions per unit of output) has to be more stringent than the emissions per unit of output under CAT. As a result, the abatement level of the industry in CT is higher than in CAT.

In spite of more intensive abatement under CT, the marginal cost of output and hence the product price is still lower than under CAT (Boom, 2006:chpt. 4). Output in long-run market equilibrium is higher in CT than in CAT. This has two consequences. Firstly, the emissions standard under CT must be more stringent than the emissions per unit of output under CAT to achieve the same target level of emissions for the industry. Higher abatement per unit of output implies higher marginal abatement costs so that the price of credits in CT is higher than the price of allowances in CAT (Boom and Dijkstra, 2009). Secondly, the adoption of an emissions trading scheme in the EU could lead to carbon leakage: the moving of investments or production, and thus emissions, to countries outside the EU where an emissions pricing system has not (yet) been adopted (e. g. Matthes, 2008). Because of its implicit output subsidy and lower product price, CT is more effective in minimizing carbon leakage than CAT (Holland, 2012; Weishaar, 2007).

3.2.3 Industry output, market structure and economic efficiency

The difference between the two emissions trading designs in terms of levels of output and abatement has consequences for their impact on welfare. We shall first discuss their differences in economic efficiency when there is perfect competition in the market for output, followed by an analysis of what the impact is when output is sold on a market with imperfect competition.

Economic efficiency when competition is perfect

Maximum welfare (or: surplus) requires (a) that the marginal production cost equals the marginal benefit of the product for each consumer and (b) that it contains all cost components. When competition is perfect, the first condition is met both under CAT and CT, but the second condition is only met under CAT. CAT is not only cost efficient but also economically efficient by transmitting the shadow price of abatement into the price of output.

Nevertheless, CT is more flexible than CAT. In an economic recession, production declines and emissions therefore decrease. CAT would then result in allowance oversupply and an allowance price drop, because the cap and thus allowed emissions do not change, unless there is a regulatory device to tighten the cap. The allowed emissions under CT, however, are automatically reduced in case of a recession, as a result of which credit oversupply would not occur. Their relative performance is reversed, however, in case of an economic boom. CT could lead to a situation where total industry emissions would overflow their target level, unless the emissions standard is tightened. CAT, however, would prevent emissions from surpassing the emissions cap, which would also increase the allowance price.

CT's aforementioned flexibility also comes at an economic cost. The supply price of the product under PSRT does not signal that abating the residual emissions of the marginal product has a cost. Consumers then buy too much of the product at a price that is too low. Welfare (the total surplus) would be higher if output were lower and abatement as well (Boom, 2006:chpt. 4). Models assuming uniform firms without emissions trading come to a similar conclusion (e. g. Helfand, 1991; Ebert, 1998; Dijkstra, 1999:chpt. 3; Fischer, 2001; Boom and Dijkstra, 2009; Holland et al., 2009). In simulations of PSRT, Boom (2006: chpt. 4) finds that the loss of surplus, because of high abatement necessary to offset the emissions of too high output, can be up to 20 % higher than the loss of surplus in CAT. Likewise, in a simulation by Holland et al. (2009) of a low-carbon fuel standard to attain a given level of CO_2 emissions in the US, it is shown that the loss in total surplus due to abatement cost is about 2.5 to 5 times higher under CT compared to CAT (depending on the elasticity of fuel supply and demand).

When competition on the allowance market and product market are perfect, CT is cost efficient but not economically efficient because the benefits of a (small) part of output are lower than the costs, due to the abatement of the extra mandated emissions of that output. CAT is economically efficient, because it reduces emissions through lower production where that is less costly than spending extra money on emissions control.

Economic efficiency when competition is imperfect

In a monopolistic or oligopolistic product market without environmental policy, output is below the economically efficient level. When the authority introduces environmental policy through CAT, the output shrinks further than if CT would be used. In this case, PSRT could have an advantage because it leads to higher output and a higher number of firms compared to CAT (Dijkstra, 1999:chpt. 3; Boom, 2006:chpt. 4). Although CT seems to bring higher welfare than CAT under imperfect competition, we have seen that CT also leads to higher abatement costs than CAT. Their ranking in terms of welfare ultimately depends on the size of these effects (Boom, 2006:chpt. 4; Boom and Dijkstra, 2009).

Building upon earlier analyses of a perfect allowance market under an imperfect output market (Malueg, 1990; Ebert, 1998), De Vries (2003:chpt. 8) finds that CAT performs better on welfare than CT when the difference in emissions per product is small but when this difference is high the ranking is reversed (see also Boom, 2006:chpt. 4, expanding e. g. Sartzetakis, 2004). Where De Vries (2003:chpt. 8) and Boom (2006:chpt. 4) maximize the consumer plus producer surplus under the constraint of an emissions ceiling, Holland (2012) maximizes this surplus minus the environmental damage from emissions. He interprets the missing emission cost component under CT as a (hidden) consumption subsidy, which can be neutralized by an equal tax on output, whereas CAT works out the way that a combination of an equal subsidy and tax on consumption would do. In a second-best world, however, welfare is maximized by setting the ‘corrective’ tax at a lower level. Despite differences in modeling and terminology, Holland’s conclusions are on a par with those of De Vries (2003) and Boom (2006).

3.4 Impact of combining emissions trading concepts on efficiency

We have shown that industry’s total output is higher, and emissions per unit of output are lower, in CT compared to CAT. Therefore, the abatement effort under CT has to be higher and consequently marginal cost of abatement is higher too compared to CAT, so that the credit price under CT is higher than the allowance price under CAT.

Now suppose that CAT is used for output sector A and PSRT for output sector B. What would happen if firms in sector B are allowed to buy and use allowances to cover emissions in sector A *et vice versa*? Fischer (2003) concludes that trade between CAT and PSRT sectors will lead to higher total emissions, assuming that the regulator will not set a more stringent emissions standard. If we drop this assumption, the government may adjust the emissions standards in the PSRT sector to avoid the total emissions ceiling being exceeded. Boom and Dijkstra (2009) show that, when trade is opened between the two sectors, the credit price is initially higher than the allowance price. Firms in the PSRT sector will buy allowances from firms in the CAT sector and trading leads to an equalization of allowance and certificate price. If the output of the two sectors is sold in different markets, firms in the PSRT sector see their average cost of output go down, so that the product price decreases and output is higher. For the CAT sector, average costs of output go up, leading to an increase in the product price and to a lower level of production. Therefore, allowing emissions trading between the two sectors leads to an increase in the discrepancy in output.

To see the similarities and differences between the above-mentioned emissions trading design concepts and the real-life EU ETS, we first have to present its basic legal rules and some of the changes therein.

4 Revised emissions trading rules

What do the rules for emissions trading and their amendments so far look like in the EU? The story begins at the end of the previous century, when a European carbon tax turned out to be politically unacceptable. After that fiasco, the European Commission set its sights on emission rights allocated for free under an emissions cap. The Commission got support from the European Parliament and from the Council of Ministers for such a cap-and-trade system, initially for the period 2008–2012. In shaping the Emissions Trading Directive 2003/87/EC, however, two political compromises were made which are totally alien to the original concept of cap-and-trade as outlined above. First, emission rights, called 'allowances' in the EU ETS, also have to be allocated for free to newcomers and expanding companies. The number of allowances for a company will be based on their output capacity. Second, member states are at liberty to decide whether the rights shall lapse on the closure of a plant. Both modifications basically merged the cap-and-trade system of the EU ETS with a credit trading system that also allows higher total emissions in case of firm expansion and does not allow the sale of emission rights when an installation closes. Fairness concerns are likely to have played a role in this decision making process (e. g. Heilmayr and Bradbury, 2011): not treating incumbents and newcomers equally would have been politically unacceptable. De Bruyn et al. (2008) point out that it is primarily the industry that advocated such modifications.

Under the amending Emissions Trading Directive 2009/29/EC, the EU set out the rules of play for emissions trading related to the period 2013–2020 (and beyond). New in comparison with the previous period is, among other things, the phased lowering of the cap rather than a constant cap. Not just CO_2, but also nitrous oxide (N_2O) and perfluorocarbons (PFCs) are now targeted. Quite surprising, from the perspective of political acceptability, is the gradual conversion from the allocation of rights for free to sale at auction. The reason for this change is the unforeseen consumer opposition against the windfall profits that electricity producers incurred by passing through the opportunity costs of free allowances in the electricity price (Woerdman et al., 2008). Another change is that each member state is now obliged to allocate rights for free to newcomers and to those investing in extra capacity (rather than this being an option for them). Furthermore, in all member states the surrendering of rights is obligatory when a plant is closed or its capacity reduced.

The total emissions cap for 2013, and thus the number of emission rights, has been determined for each member state. In the period 2013–2020 the cap in each member state is lowered by 1.74 % per year. The amending 2009 Directive stated that ultimately all allowances are intended to be sold at auction: starting with 20 % of the total in 2013, increasing annually up to 70 % in 2020 and finally intended at 100 % in 2027. This process is speeded up in the power sector: in this sector all rights are sold at auction since 2013, except in East European member states where this must be achieved by 2020. Member states are free to decide how to spend the auction revenue, but the political intent is that at least 50 % of this revenue is used for climate measures.

An exception has been made for carbon-intensive sectors competing on an international product market with companies established in countries where no emissions cap applies: 100 % of the allowances allocated to these sectors is allocated for free during the entire period 2013–2020. The number of emission rights available for this category declines in line with the total cap for all companies. The giving away of allowances to established companies takes place on the basis of a carbon standard per unit of production multiplied by production in 2005 (or the average for 2005–2007 if this is higher). This standard, referred to as 'ex ante benchmark', is determined based on the average emissions of the 10 % installations with the lowest carbon emissions per unit of product or energy output in an industrial sector in the years 2007–2008. Early 2018 the European Council approved the legislative proposal for the EU ETS after 2020, published by the Commission in 2015 (COM, 2015 337 final), which continues the free allocation of allowances to carbon-intensive sectors for the period 2021–2030.

The EU's decision to make the sale of allowances at auction the principle, and allocation for free the exception, contradicts the view that regulated companies largely dictate the rules for an emissions trading system. However, at the time the decision to auction allowances was taken, the lobbying by regulated energy companies and industrial sectors was counteracted by an unanticipated lobby of electricity consumers. Emission rights had been handed out for free to electricity producers that passed on the opportunity cost of the free allowances in the price of electricity. Profits of the electricity industry swelled, as economic theory predicts. This led to political turmoil after the start of the EU ETS in 2005 (Grubb and Neuhoff, 2006). Consumers refused to swallow the increase in the price of electricity, full of indignity about having to pay for something obtained for free by the manufacturer (Woerdman et al., 2009). This consumer opposition gave the European Commission the political room to impose allowance auctioning on electricity producers and to start with a transition towards auctioning for the exposed industry.

Where allowances are (still) allocated for free, regardless of the sector, newcomers and established companies expanding their production capacity (in excess of 10 %) are allocated rights for free as well. A new entrants' reserve has been created for this category, equalling 5 % of the total number of rights. The allowances are allocated for free or sold at auction in the same way as this is done for comparable established plants. In the case of plant closure and a significant cutback in production capacity, the rights obtained for free have to be surrendered. Any rights left over in any year after deducting rights allocated for free are sold at auction. Any rights remaining in the new entrants' reserve are also sold at auction. The rule stipulating that all allowances not allocated for free must be sold at auction is aimed at ensuring that the full quota of available rights enters the market each year.

The allocation of free allowances for newcomers and for major expansions is, in principle, based on the capacity of the production facility, measured by its potential standardized emissions. However, in subsequent decisions in the year 2011 (on the basis of the so-called 'Comitology' procedure), the EU has elaborated the new rules by implicitly bringing in the level of operations relative to capacity as an additional criterion for the allocation of free allowances. A 'partial cessation of operations' (PCO) rule stipulates that if the level of operations (e. g. production) is cut back below a given percentage of potential operations (hence capacity) for which allowances have been handed out, the number of free rights will be adjusted in discrete steps (COM, 2011: 43). Roughly speaking, if production decreases by less than 50 % no emission rights will be lost, but 50 % of the initial rights will be cancelled if production falls to a level between 50 % and 25 % of capacity. Allowances are reduced to 25 % of capacity if production is lowered to less than 25 % but still above 10 % of capacity. A reduction of production to less than 10 % of capacity leads to cancellation of all free allowances. If production is increased again and exceeds these threshold percentages, free allowances are adjusted upwards accordingly.

To tackle the problem of over-allocation of allowances, the Council of Ministers of the EU decided in 2015 to add a Market Stability Reserve (MSR) to the EU ETS (COM, 2014 0020 final). Although this is an important step in addressing oversupply, we will not discuss the MSR since this reserve does not change the operation of the EU ETS based on its expansion and closure rules. Moreover, the EU ETS will operate under revised rules as of 2021, in which the allocation of free allowances will be based on actual production figures instead of production capacity (Directive (EU) 2018/410). Although this is highly relevant, our paper analyses the rules of the current compliance period (2013–2020) in comparison with the previous periods (2005–2012), leaving an analysis of the rules that will apply in the next period (2021–2030) for future research.

5 Economic consequences of the revised rules

This section focuses on the industrial sectors exposed to international competition where all allowances are allocated for free. Two questions will be answered. Firstly, how does the revised set of rules for free allowances under the current

EU ETS (2013–2020), as described in the previous section, operate from the perspective of efficiency? Secondly, what are the similarities and differences in design and performance of the EU ETS compared to cap-and-trade and tradable reduction credits?

To answer these questions, a distinction must be made between the corporate decision regarding the expansion of capacity and its decision on how to use installed capacity. The decision on capacity is for the long run which involves expectations on long-run demand for output, including uncertainties about its future development. Firms under the EU ETS that are exposed to international competition have the additional option to plan capacity because they can then claim free allowances that might possibly be sold at a profit. The decision to use capacity that has been installed, fully or partly for the production of output, is a short-run decision for a year or an even shorter period. Firms under the EU ETS that receive allowances for their capacity have the option of not using the full capacity for producing output which gives them scope for selling allowances.

The next two subsections will clarify how the EU ETS influences the two aforementioned decisions and their efficiency. We will first discuss the corporate decision on capacity and then on output. To make our stylized exposition as simple as possible, we make four assumptions that should be stated from the outset:

(a) we assume the same emissions price under cap-and-trade and under credit trading;
(b) we assume that abatement costs are part of the fixed cost of capacity in the firm's long-run decision on capacity and that in the short-run decision the firm complies with the restriction on its emissions by adjusting output in combination with buying or selling allowances;
(c) we assume that the firm gets exactly as many emission rights per unit of output as it needs;
(d) we assume that the operations in a new installation of an existing firm that has expanded its capacity do not affect profits in the rest of its business.

We wish to stress that these assumptions can only generate a partial analysis, for instance because emission prices would differ between cap-and-trade (lower) and credit trading (higher) in reality.

5.1 The corporate decision on capacity

New companies and companies expanding capacity face a choice: capacity can be planned (a) for producing output, (b) for claiming allowances, or (c) both.

If similar established plants are already receiving allowances for free, allowances are also allocated for free to companies expanding their capacity. In our discussion of decisions under the various instrument variants, we shall focus on the individual firm and assume it operates on a market for output and a market for allowances with perfect competition. As a consequence, price Pq for output q and price Pa for allowances are given. Furthermore, the variable production cost V, expended on raw materials, fuels and labour, is constant per unit of output. Per unit of output one allowance is needed to cover emissions. The total fixed cost of capital invested in capacity for 100 units of output is F, made up of depreciation, interest and a surcharge for profits. Therefore, the normal fixed cost per unit of output (with full use of capacity for producing output) is F/100 = fn.

To assess whether investing in expansion of capacity fully used for the production of output is profitable, the revenue of output has to be compared with the cost of output. Crucially, what is included in the cost depends on the design of the emissions trading instrument. In a pure cap-and-trade scheme the cost components are the fixed cost of capacity, variable production costs and the opportunity costs of allowances. Using symbol q for output, the condition for making profits is then (Pq − V − Pa).q > F, or per unit of output (Pq − V − Pa) > fn. Under credit trading, mandated emissions are for free and the condition for profits is (Pq − V) > fn. The same holds for the EU ETS (before as well as after the introduction of the PCO rule): the allowances needed to cover emissions released in producing the good are not part of the cost of output because they come for free with the additional capacity. The condition for making a profit on output, with full use of capacity, is (Pq − V) > fn. In planning capacity for output, the EU ETS therefore operates in a way similar to a credit trading scheme. However, before the PCO rule was introduced in the EU ETS, the management of the firm had the alternative to invest in expansion of capacity with the aim to sell the allowances granted for the added capacity. Investment exclusively for receiving allowances is profitable if the allowance price exceeds normal fixed cost (both calculated per unit of output): Pa > fn. Evidently, management will choose to invest in capacity for output if (Pq − V) > Pa.

In Table 1 the decisions on capacity in four design variants of emissions trading are compared for various price scenarios. The first price scenario in the table assumes a relatively high price of output, which results in the net revenue of output exceeding the allowance price, hence (Pq − V) > Pa. Further we assume (Pq − V − Pa) > fn. Expected profits from investing in capacity for output are positive in all four designs of emissions trading and in the EU ETS they are higher than investing in capacity for the allowances they yield. As a consequence, management plans capacity for output.

Table 1: Capacity planning under four emissions trading designs.

Prices and costs	EU ETS without PCO rule	EU ETS with PCO rule	Credit trade	Cap-and-trade
(Pq − V) > Pa > fn ***Scenario 1***	Plan additional capacity for output	Plan additional capacity for output	Plan additional capacity for output	Plan additional capacity for output
Pa > (Pq − V) > fn ***Scenario 2***	Plan additional capacity for allowances	Plan additional capacity for 50 % allowances and 50 % output	Plan additional capacity for output	Plan no additional capacity
Pa > fn > (Pq − V) ***Scenario 3***	Plan additional capacity for allowances	Plan additional capacity for 50 % allowances and 50 % output	Plan no additional capacity	Plan no additional capacity
Pa < fn > (Pq − V) ***Scenario 4***	Plan no additional capacity	Plan no additional capacity	Plan no additional capacity	Plan no additional capacity

Price scenario two has a high allowance price relative to the net revenue of output. Investment in capacity for output is then not economically feasible in cap-and-trade, but it is in credit trading, as is shown in Table 1. In an EU ETS without PCO, investment in output and in allowances are both economically feasible, but investment in capacity to receive allowances is the most profitable one, since Pa > (Pq − V). The EU ETS with the PCO rule sets a restriction on obtaining free allowances for capacity (COM, 2011: 43). To be entitled to allowances corresponding with a full capacity level of operations, at least 50 % of capacity should be used for producing output. When it is lower, at least 50 % of the free allowances granted for capacity is cancelled. The PCO rule ensures that planning capacity solely for obtaining allowances is legally not a feasible option. The second-best choice is to plan capacity that will be used for 50 % to produce output and for 50 % to obtain allowances. In order to make positive profits the 'joint' product, consisting of 0.5 unit of output plus 0.5 allowance, should exceed the normal fixed cost per unit of installed capacity: 0.5 (Pq – V) + 0.5 Pa > fn. Price scenario two assures that the condition is fulfilled and that the investment delivers a profit. Although profit is lower than from investing in capacity exclusively for allowances as was possible before the introduction of the PCO rule, it is higher than profit from investing in capacity solely for output.

In price scenario three the price of output is so low that the net revenue of output (Pq − V) is below the normal fixed cost of capacity per unit of output fn. The net revenue of output can even be negative. Planning capacity for output is neither economically feasible in cap-and-trade nor in credit trade. In an EU ETS without PCO rule investment in capacity for allowances would be profitable thanks to the high price of allowances (one per unit of output) which exceeds the normal fixed cost of capacity per unit of output. In the EU ETS with PCO rule that option is closed. However, it is legally possible and economically feasible to plan partially for output as a strategy to obtain allowances that can be sold on the allowance market: 50 % use of capacity for output entitles the firm to 100 % allowances of which 50 % can be sold. Such investment in capacity is profitable as long as the price of allowances is sufficiently high to overcompensate the loss on selling the associated unit of output; that is (Pa − fn) > (Pq − V − fn). It then makes planning of capacity half for output and half for allowances the only profitable option in the EU ETS with PCO rule. Planning based on 50 % capacity use, of which 25 % for production of output and 25 % used for receiving the extra allowances would double the normal fixed cost per unit of output compared to the 'fifty-fifty' option. It is evidently less profitable and therefore irrelevant for capacity planning (which is even more true for planning capacity producing at 10 % capacity use to obtain 25 % of potential emission allowances).

Finally in price scenario four the price of allowances and the net revenue from output are both below normal fixed cost. In that case, in none of the four design variants of emissions trading planning expansion of capacity is profitable.

To assess the efficiency of the four design variants in relation to planning capacity, we first compare the results for price scenario two in Table 1. Here the EU ETS with PCO rule looks like a compromise between the EU ETS before the PCO rule and credit trading, with respect to its incentive on the purpose of the capacity investment. However, in price scenario three it turns out that if the price of output is so low that credit trading is economically not feasible, the EU ETS with PCO rule still encourages investment in capacity. We have observed before that credit trading is inefficient due to its hidden subsidy in the form of free mandated emissions per unit of output, whereas in cap-and-trade each unit of emissions has a price which makes the scheme efficient in total output and abatement. The EU ETS with PCO rule adds to the inefficiency of credit trading by granting one extra free allowance next to the free allowance used to cover the mandated emissions of a unit of output. Therefore, from a social welfare point of view, capacity created for the allowances they deliver constitutes a waste. We conjecture that the insertion of the PCO rule is intended to mend this potential inefficiency, but the repair is only partial and has the impact of strengthening the incentive to plan capacity basically for the sake of the allowances that can be claimed.

In price scenarios two and three the allowance price is so high that the market value of allowances used to compensate CO_2 emissions per unit of output exceeds the net revenue of output and also the fixed cost of capacity (mainly depreciation and interest) per unit of output. Is it possible that in the period 2013–2020 such a situation has been or might become real for individual firms within the various industries under the EU ETS? To provide an illustration we have selected the iron and steel industry of the EU, which is one of the highest emitters in the EU ETS and also one of the sectors most exposed to international competition. The price and costs for the product 'hot rolled coil' are presented in Table 2, referring to iron or steel rolled at very high temperatures (Metal Bulletin Research, 2009).[1]

Table 2: Price and costs per metric ton of 'hot rolled coil' (Q4 2009 at price level 2018).

Price	€ 409.70
Variable costs	€ 342.50
	– ______
Net revenue from investing for output (Pq – V)	€ 67.20
Capacity costs per unit of output (fn)	€ 54.90
	– ______
Profit from investing for output (Pq – V – fn)	€ 12.30
Revenue from investing for allowances (Pa) 1.8 x € 13.50 =	€ 24.30

The outcome of Table 2 is that (Pq – V) > fn > Pa. Note that, here, Pa = € 24.30 stands for the revenue of the allowances that become available by not producing one unit of output. If the metal corporation's management was to base its long-run expectations on the current rules of the EU ETS and on our simulation of 2018 prices and costs, it would conclude that scenario one is relevant. Given the

1 The figures have been converted from dollars into euros at the average exchange rate of 2009, that is € 0.72/$ and are expressed in prices of 2018 using the historic harmonized inflation rate for Europe which is 13.8 % for the period 2009–2018. The CO_2 emissions rate of 1.8 ton of CO_2 per ton of crude steel is based on the blast furnace and basic oxygen furnace production processes (Wörtler et al., 2013) and assuming a reduction of the CO_2 emissions rate by 5 % due to technical progress over the period 2010–2018.

price and costs of output, scenario two steps in if the revenue of allowances, calculated per unit of output, exceeds the € 67.20 of net revenue that would be cashed if the unit of output was produced and sold, and the allowances used to compensate the emissions. That would imply a price per allowance higher than € 37.33, whereas the actual allowance price in April 2018 was between € 13 and € 14. Scenario three can only become actual if the net revenue of output sinks below the capacity cost of € 54.90 per unit of output. That could happen due to a fall in the price of steel of 3 % or more, and hand in hand with a price per allowance above € 30.50. Such a coincidence would bring the net revenue from investing in capacity for output below the profit from investing in capacity for allowances. Scenario four, with no investment in capacity, would materialize after a drop in the price of steel similar to scenario three and with the price per allowance at a level of e. g. €13 to €14 as it was in April 2018. The figures thus suggest that for the period 2013–2020 scenario one is the most likely scenario and scenario four a possibility.

However, an important qualification needs to be made with respect to the data of Table 2, namely that this numerical illustration only gives a rough indication. In the real world there is a considerable variety in types of steel products and their prices as well as in the production processes and their costs. Variations in product price and variable cost can make that at times net revenue of output is negative. Under such circumstances scenarios two and three will become a reality only if the firm's management strongly believes that the momentary relation between prices and costs is here to stay.

5.2 The corporate decision on output

Once capacity has been installed and operations have started, a firm needs to make decisions frequently on the level of output and of allowance sales for the current period. Markets change: demand and market prices today can diverge from those in the past. Suppose that the present price of output is below the level expected when capacity was planned. However, the capacity is there. The fact that it is partly redundant for production cannot be undone and the cost of capacity is sunk. The loss has to be taken and the cost of capacity is not included in the short-run costs of producing output. This holds for all four designs of emissions trading. In an EU ETS without PCO rule it has a peculiar consequence for the manner in which the scheme operates. The existing capacity determines the number of free allowances allocated to the company. The alternative for using those allowances for production is to sell them on the allowance market. There is now an opportunity cost attached to the use of allowances to cover emissions generated in producing output, because by using the allowances the company foregoes the revenues it would have obtained if it had sold those rights. Consequently, in the short run when capacity is given, the opportunity cost is part of the cost of the product in an EU ETS without PCO rule. Producing output gives a profit if the price of output exceeds the cost, which in the short run consist of variable production cost plus the opportunity cost of the allowances. The cost of output in an EU ETS without PCO rule is then equivalent to the cost of output in the textbook model of cap-and-trade. In both schemes, the allowance price is a component of the cost of output, while in both schemes capacity costs are not included in the short-run costs of output. Therefore, in the short run an EU ETS without PCO rule is equivalent to cap-and-trade, which can also be seen in Table 3. It should be noted that in discussing the short-run decision on output we shall assume that in all five scenarios the available capacity is equal to the expected long-run level of price scenario one. Therefore capacity is never a constraint on output, but capacity is partly or fully redundant for the production of output in short-run price scenarios two through five.

Table 3: Short-run output and allowance sales under four emissions trading designs.

Prices and costs	EU ETS without PCO rule	EU ETS with PCO rule	Credit trading	Cap-and-trade
$(Pq - V) > Pa > 0$ ***Scenario 1***	100% output 0% allow.	100% output 0% allow.	100 % output	100% output 0% allow.
$Pa > (Pq - V) > 0$ ***Scenario 2***	0% output 100% allow.	50% output 50% allow.	100% output	0% output 100% allow.
$Pa > 0 > (Pq-V) > -0.875Pa$ ***Scenario 3***	0% output 100% allow.	50% output 50% allow.	0% output	0% output 100% allow.
$-0.875Pa > (Pq-V) > -1.5Pa$ ***Scenario 4***	0% output 100% allow.	10% output 15% allow.	0% output	0% output 100% allow.
$(Pq-V) < -1.5Pa$ ***Scenario 5***	0% output 100% allow.	0% output 0% allow.	0% output	0% output 100% allow.

After capacity has been installed, its costs are sunk. They are not a part of the short-run cost when the decisions on output and possibly on allowance sales are made. It means that to make Table 1 relevant for the short run, one has to set $fn = 0$ in its first column; by doing so one gets the first two price scenarios of Table 3 and the first terms of price scenario three.

We shall first discuss the EU ETS without and with the PCO rule. In the short run, the available capacity can be used for producing and selling output or for selling the allowances that have been gained and are fixed in number. In an EU ETS without PCO rule the costs of output consist of the variable production cost plus the opportunity cost of allowances. In price scenario one in Table 3 the net revenue of output (Pq − V) is higher than the revenue from not using the allowance for production but selling it (Pa). The firm will therefore use 100 % of capacity for producing and selling output. This decision is consistent with its planning of capacity for output: the firm has planned capacity for output and will sell output.

In a similar way one calculates that in price scenario two, with its relatively high allowance price, the firm has planned capacity for allowances in an EU ETS without PCO rule and in the short run it will sell allowances. The consistency between long-run and short-run decisions is the consequence of prices that in the short run do not deviate from the price expectation for the long run on which capacity planning was based. However, using capacity exclusively for the entitlement it gives to free allowances is no option under the PCO rule: using 50 % of capacity for allowances is the (legal) maximum, implying that the other 50 % has to be used for output. Per unit of capacity (of which the cost is sunk) the firm delivers a 'joint' product, as we said before, defined as 0.5 unit of output plus 0.5 allowance. Given the relatively high allowance price, the short-run revenue of the 'joint' product is more profitable than using the full capacity for production and selling the output. Again the decision for the short run is in line with the investment in capacity planned for the long run. In the numerical illustration provided in Table 2 and assuming an allowance price of € 13.50, the switching point that makes scenario two real is attained when the net revenue of output of € 67.20 is equal to the potential revenue of allowances set free by not producing a unit of output, that is 1.8 x € 13.50 = € 24.30. The difference is considerable and makes scenario two not very likely for the period 2013–2020.

When a firm uses 50 % of capacity for producing output, the PCO rule implies that next to the allowance to compensate emissions the firm receives per unit of output one allowance that can be sold. It is a subsidy in kind, which may give the firm an incentive to accept production of output that can only be sold at a loss. This is profitable if the revenue of selling an allowance (Pa) exceeds the negative short-run revenue of a unit of output (Pq − V). However, the switch to the company's last stand option of setting output at 10 % of capacity, which entitles the firm to receive allowances equal to 25 % of capacity (that is 2.5 allowances per unit of output), is already attained before the loss on output has fallen to equality with the allowance price. The breakeven point for switching is where the profits of the two options are equal, that is 50

$(Pq - V) + 50\,Pa = 10(Pq - V) + 15\,Pa$. The solution is $(Pq - V) = -\,0.875\,Pa$. It is in Table 3 the lowest feasible (negative) net revenue per unit of output in scenario three.

When $(Pq - V)$ is even lower than $-\,0.875\,Pa$, then the firm is in scenario four. Assuming in scenario four an allowance price of € 13.50, and therefore a potential revenue from selling allowances instead of output of 1.8 x € 13.50 = € 24.30, the breakeven point for a switch to 10 % use of capacity for output is attained when the net revenue of output is negative and equal to $-\,0.875 \times$ € 24.30 = € − 21.26. That would happen if the price of output would fall by 5.2 %. Note that at a lower allowance price of € 7, as it has been for a long time in the period 2013–2020, a drop in the steel price of 3 % would suffice to make scenario four real.

Thanks to the 1.5 allowance subsidy additional to the allowance needed to cover emissions from producing the output, total profits in scenario four are positive as long as the negative net revenue of output is less than 1.5 times the price of an allowance. In price scenario five a loss on output of more than 1.5 times the allowance price forces management to terminate output and accept that all allowances for capacity are cancelled.

We now turn to comparing the levels of output and (if relevant) of allowances in the four different design variants of emissions trading in Table 3. The table shows in scenario one, with the net revenue of output above the allowance price, that in the short run capacity will be fully used for producing output in all four designs and no allowances will be left. In scenario two, where the net revenue from selling output – albeit positive – is lower than the allowance price, the firm operating under a cap-and-trade scheme will stop using capacity for the production of output and sell its unused allowances. This would also occur in an EU ETS without the PCO rule. A difference, however, is that in the textbook model of cap-and-trade the firm will shut down capacity in the long run in response to persistently lower output, whereas in an EU ETS without the PCO rule capacity will be maintained to retain allowances.

The introduction of the PCO rule changes that: in scenario three, half of capacity is used for output and half of capacity is kept for the free allowances it yields, which are then sold. The strategy can be sustained, even when the short-run net revenue from output is negative and the allowance price is high enough to overcompensate the loss, as it is in scenario three. The fourth scenario shows that it is even possible to survive a loss of just below 1.5 times the allowance price by using 10 % of capacity for production of output. By contrast, in a credit trading scheme the firm will terminate production completely as soon as the short-run net revenue from output is negative, as happens in scenario three.

In the scheme of cap-and-trade we assume that allowances have been allocated for free and capacity is such that all free allowances are used for covering emissions if capacity use is at 100 %. When the firm decides not to use capacity for producing output it can sell all allowances.

By comparing Tables 1 and 2 we get the full picture of how the PCO rule influences corporate decisions. Table 1 shows that in the EU ETS with PCO rule planning of capacity for output comes to a halt when the net revenue of output and price of allowances – although both still positive – have fallen below the normal fixed cost of capacity (per unit of output). With regard to planning of output on existing capacity, Table 3 shows that producing output does not stop before the net revenue of output has plunged so deep in the negative that even a subsidy of 1.5 times the market value of allowances granted per unit of produced output is of no help. The PCO rule is therefore an instrument to support industry in continuing production on existing capacity in times of low to very low prices of output. The allowance subsidy will have far less impact in stimulating investment in expansion of capacity because that requires an implausibly high allowance price.

5.3 'The devil is in the PCO rule'

As we have seen above, successive adjustments to the EU ETS have brought about remarkable transformations in an emissions trading system that was initially set up on the basis of an efficient cap-and-trade design feautures. The regulatory changes have altered long-run planning of capacity as well as short-run output decisions. In particular the amendment of 2009 to grant free allowances for output capacity as of 2013, instead of the original absolute cap on emissions per firm, changed the cap-and-trade scheme into a hybrid system. Firstly, in a company's long-run planning of output capacity this hybrid works out in a way similar to credit trading. Secondly, with regard to making the short-run decision on output this hybrid kept the features of cap-and-trade: output is set at a level lower than in a pure credit trading scheme. However, the introduction of the PCO rule in 2011 brought a far-reaching change in the incentives that drive the management's decisions in long-run planning of capacity as well as in the short-run plan on the use of capacity for producing output. With regard to capacity use for output, Table 3 reveals that in the face of a shrinking demand for output that show up in an ever declining product price, the EU ETS with the PCO rule succeeds in keeping production of output going where in the three other design variants of emissions trading output has to be terminated (sooner or later). The explanation lies in the double implicit subsidy embedded in the EU ETS with PCO rule: (1) the subsidy in the form of free allowances in relation to planning capacity of output, and (2) the subsidy in the form of extra allowances when capacity is not fully used for producing output. We have shown above that the latter can increase to such an extent that it covers 150 % of the loss on output. Where the first type of subsidy is also granted in a credit trading scheme, the second one is unique for the EU ETS in its present design. As always, 'the devil is in the detail': the introduction of the PCO rule is a regulatory addition that nevertheless marks a striking U-turn in how the EU ETS works out in periods of a very low product price relative to the allowance price.

6 Impact on carbon leakage and competitiveness

According to Article 10 of the amending Emissions Trading Directive 2009/29/EC, the new rules have been designed for the purpose of (a) preventing carbon leakage and (b) protecting the competitiveness of exposed industries. As explained before, carbon leakage refers to the relocation of companies, and thus emissions, to countries outside the EU where an emissions pricing system has not (yet) been adopted. There was and still is discussion about how big this problem will become in reality. There has hardly been any carbon leakage from the EU in the past (e. g. Dechezleprêtre et al., 2014; Naegele and Zaklan, 2019) and various authors also expect only limited (or even negative) leakage for the future (e. g. Heilmayr and Bradbury, 2011; Gerlagh and Kuik, 2014). The latter is indeed a plausible scenario, because the number of carbon pricing schemes around the world is steadily increasing (World Bank et al., 2017: 26–27), because policy-induced low-carbon innovations are likely to spread across countries and because other cost factors than the relatively limited EU ETS compliance costs are more important in the decision whether or not to relocate investments or production abroad (e. g. Sijm et al., 2004; De Cian and Parrado, 2018). Evidently, the minimization of carbon leakage goes hand in hand with a mitigation of the negative effects that European climate policy has on the competitive strength of fuel-intensive EU firms operating on the world market. For a given carbon leakage risk, Martin et al. (2014) calculated that the current rules of the EU ETS lead to substantial overcompensation. What can we conclude based on our conceptual analysis of different emissions trading design variants? In other words: what will the contribution of the EU ETS be to the aforementioned two objectives (of Article 10)?

In a worst-case scenario, a dramatic fall in world market demand for output of the exposed sector lets the price sink so deep that the net revenue per unit of output becomes negative, but (in absolute terms) not more than the allowance price, similar to price scenario three in Table 3. As a reaction, companies will refrain from expanding capacity and curtail the use of existing capacity for production of output to 50 %. The EU ETS has the feature that – unlike credit trading – it raises the implicit subsidy in years of depressed demand for the output of exposed sectors. The position of exposed European firms on the world market is strengthened when they most need it which may keep plants and their fuel-intensive output within the EU. Compared to cap-and-trade this advantage is not so clear. Using a real-business-cycle model, Fischer and Springborn (2011) find that cap-and-trade has the property of damping the volatility of output compared to credit trading. If one accepts this finding, cap-and-trade does without subsidy what the EU ETS performs only thanks to its implicit subsidy. The *caveat* here is that Fischer and Springborn (2011) have modelled a closed economy, while our analysis relates to an open economy. A fall in product price, initially seen as temporary, could be the first signal of structural change with world demand turning away from established sectors in favour of upcoming new industries. Under such circumstances, we have shown that the EU ETS would basically prolong the death struggle of a doomed industry.

Extrapolating present trends in the exposed sectors until 2020 and based on the *EU Reference Scenario* even to 2030 (Capros et al., 2016), we see price scenario one in Tables 1 and 2 as the most plausible for the near future: the price of output exceeds the normal fixed cost of capacity plus variable production cost and also the cost of allowances. In their long-run planning of capacity and in the short-run decision on output, companies in the exposed sector under the EU ETS with PCO rule have exactly the same cost as they would have to make under a credit trading scheme. Capacity and output are higher than under a pure cap-and-trade scheme and this capacity will be fully used for output. The free allowances for capacity are not an opportunity cost and therefore not included in the cost of output, which strengthens the position of the exposed European sectors on the world market so that the risk of carbon leakage is lower than it would be under a pure cap-and-trade scheme.

However joyful as this scenario may be for the exposed industries, the success of the EU ETS in supporting their competiveness and in lowering potential carbon leakage comes at the price of higher costs of reducing greenhouse gas emissions. In planning for the long run, the opportunity cost of free allowances is not signalled in the long-run marginal cost of output of the exposed sector. When the markets for output and allowances would have outcomes that come close to perfect competition (an assumption that we will relax below), the levels of both capacity and output of the exposed sector are inefficiently high. Furthermore, the boost given to output of the exposed sectors, compared to other sectors that have to buy all allowances at auction, tends to raise emissions in the EU. This therefore requires more stringent carbon standards per unit of output than the carbon emissions per unit of output would have been if a cap-and-trade scheme were in place, thus pushing up the costs of abatement of CO_2 emissions in all sectors. The total costs of emission reduction are higher than they would be without the special protection that the EU ETS in its present design gives to the fuel-intensive exposed sector. An extra complication is that companies in the non-exposed sectors (mainly electricity producers) have to buy all their allowances at auction, that is, in a cap-and-trade scheme. From our theoretical exposition given above, it follows that when allowance trading is permitted between the two distinct markets for emission rights, companies in the exposed sector in need of credits prefer to buy allowances in the non-exposed sector, either at auction or from companies, because the allowances are cheaper than credits. In the new equilibrium, the merged market has a uniform price for allowances and credits. The exposed sector will benefit from lower cost, a stronger export position and higher output, to the detriment of the non-exposed sector where costs of mitigating emission of greenhouse gases are now higher and output lower. In this way the inefficiency in the exposed sector spills over to the non-exposed sector and enhances the welfare loss caused by the design of the EU ETS for the exposed industries.

Instead of assuming perfect competition one might adopt the view that markets for output in the EU are characterized by imperfect competition. In a Cournot model, De Vries et al. (2014) show that cap-and-trade entails higher welfare than credit trading, because the latter leads to too many clean firms in long-run equilibrium (assuming free entry and exit). In our paper, however, we analyse the hybrid case of the EU ETS. Suppose that there is market power with high product prices leading to a level of output below the welfare maximizing level. If that were the case, our analyses above suggests – in (plausible) price scenario one – that the current EU ETS with the PCO rule will function as a credit trading scheme pushing up output to a level closer to the welfare maximum. This may sound desirable from a law and economics perspective, but we wish to stress that it is not. Firstly, it is a complete contradiction to bemoan on the one hand a sector as being exposed to murderous international competition and on the other hand to qualify it as an industry with the market power to set prices. Secondly, in our view the second-best policy idea to correct a distortion of competition on one (product) market by creating a distortion on another (allowance) market is a blunder. Implicitly, this view assumes a holistic regulator in the EU with almost perfect knowledge and control. In the absence of a such a European authority, we recommend straightforward first-best policies. We advise to attack the distortion where it appears: should there be market power in the exposed sector then antitrust policy would have to be applied, while the problem of climate change requires a cap-and-trade policy.

The EU made an excellent start by choosing cap-and-trade as the flagship of its climate policy, but the devil is clearly in the details of emissions trading design. The EU ETS has evolved into a sub-optimal instrument not by chance but by choice, which points at regulatory failure. In an undesirable scenario, countries or regions considering the introduction of greenhouse gas emissions trading may follow the bad example set by the EU that choses to erect special protection rules for the fuel-intensive exposed sector. In that case, the world ends up with (perhaps some linked) emissions trading schemes that come close to credit trading for fuel-intensive sectors exposed to foreign competition, which basically amounts to an international system of hidden output subsidies for exposed sectors. Unlike some other authors, such as Meunier et al. (2014), we do not think that full-blown credit trading (or: 'output-based allocation') for the exposed sector is the efficient way to go for the EU ETS. Instead we argue in favour of the first-best solution of cap-and-trade which avoids the aforementioned subsidies by directing the costs of residual emissions to the sectors where they are actually made.

7 Conclusion

Emissions trading is an effective and efficient instrument for climate policy provided that policymakers stick to cap-and-trade. Under cap-and-trade every unit of emissions has a cost, also in case of free allocation. Under credit trading, however, a firm only pays for abatement and not for mandated residual emissions which therefore entails an implicit output subsidy.

The EU currently operates a hybrid system for trade in greenhouse gas emissions, combining elements of both cap-and-trade and credit trading (or: performance standard rate trading). We have demonstrated that the legal rules based on this hybrid may trigger overinvestment in energy-intensive production capacity. Inefficiencies in the current period 2013–2020 arise in particular from the rules that tie mandated emissions to production capacity and to the utilization degree of that capacity. The result is a sub-optimal EU Emissions Trading 'Hybrid' ('EU ETH') that makes the reduction of greenhouse gas emissions more costly for society than ought to be.

In designing climate law the EU had to make a choice between maximizing efficiency or minimizing carbon leakage. In the preparation phase, policymakers focused on economic efficiency by selecting cap-and-trade. The cost of containing carbon emissions (in terms of loss of consumer plus producer surplus) is then minimized, while the possibility of some carbon leakage is accepted. However, consecutive changes to the rules of the EU ETS softened the climate regime for the industrial sectors that are exposed to international competition. This brought an essential reversal. In times of thriving output markets, the EU ETS in its present form functions for the exposed industries as similar to credit trading. In a structurally declining market for output, the current scheme would even surpass credit trading in inefficiency.

Over the years, European policymakers have thus chosen to prioritize the minimization of carbon leakage to the detriment of economic efficiency. This is a questionable choice, not only because carbon leakage has remained limited so far, but also because the number of carbon pricing schemes around the world is steadily increasing. The EU ETS will continue to operate under hybrid rules in the next period 2021–2030, but then the allocation of free allowances will be based on actual production figures instead of production capacity. Future research will have to assess the (in) efficiency of this reform under the upcoming fourth trading period of the EU ETS.

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